Final Report
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Quantitative Evaluation of Water Needs in Citrus Nurseries Using Three Different Irrigation Systems For Seedling Production

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Introduction

The purpose of this research was to quantify the irrigation needs of the Citrus Greenhouse Industry to produce seedling trees for budding. Currently these greenhouses normally germinate seeds in seedling trays and transplant them into 4 x 14 inch citrus pots to grow until they achieve trunk calipers large enough to bud. During the seedling tray stage, trees are usually irrigated using overhead irrigation systems, or less commonly some type of sub-irrigation. A few greenhouses have been evaluating or using Aquamat, a self-contained sub-irrigation system. Aquamat is a 4 layer system that has an impervious bottom layer that is sealed to the top layer, which has pin-size holes for water to pass through. In-between these two outer layers, the bottom layer is a synthetic mat that holds water and allows it to migrate to the strongest sink, i.e. trees with the highest demand for water. The middle inside layer is a spun polyethylene spongy material that separates the upper covering from the bottom water holding mat. This normally reduces free water from penetrating through to the upper layer and evaporating. When a container is set on the mat, the weight of the container compresses the spongy layer and allows water to transverse to the bottom of the pot and up into the substrate. The interior mats are supplied water through 2 drip tubes that run the length to the mat.

During seedling production, seeds are usually sown in trays consisting of a series of conical tubes. Tube lengths vary, however 6 inch deep tubes are commonly used. Tubes are generally filled with a relatively fine substrate usually a blend of Canadian peat moss, perlite and vermiculite. One or 2 seeds are planted about ½ inch below the top of the cone and the cones are filled to the top. The substrate is kept moist and nutrients supplied using liquid fertilization as needed until seedlings are large enough to be transplanted into production containers. There they are grown until the root stock trees have a minimum of ¼ inch caliper 5 inches above the substrate. Depending on demand, sometimes these rootstocks will be held over and not budded until trunk calipers are nearing 3/8th inch.

The objective of this research was to determine the irrigation need from seed sowing until seedling trees were of budding size. This was to be determined for 3 types of irrigation available to the industry during seed germination and growth in cell trays; overhead irrigation, an ebb and flow (flood) sub-irrigation system, and Aquamats. Concurrently, measurements of actual tree water use (ET_A) were to be recorded.

Materials and Methods

Seeds of Kuharski Carrizo were sown the last 2 weeks of January 2014 in 48 cell conical trays (Stewe & Son, Beaverton, OR) that were 6 inches deep and filled with a peat:perlite:vermiculite mix (Fafard #2). Twenty-five of these trays were placed on each 4 x 7 ft table, filling a table with a total of 1,150 seeded cells. Each cell was planted with 1 seed.

Cell trays that were overhead irrigated were set on an open wire mesh. Trays on the flood system were set in on a solid table top covered with plastic film with 1 inch sides and 2 drain holes ¾ in. in diameter. Single mats of Aquamat were also laid on a solid table top, but without sides or drain holes. Irrigation was supplied as needed, beginning 5 min after midnight. Each irrigation regime was replicated 3 times, resulting 9 tables of seedlings.

Irrigation frequency for both seedling trays and trees in 4 x 14 citrus pots was based on the ET_A (actual evapotranspiration). For seedlings, 4 trays from each table, one tray in from the edge were measured. For trees in citrus pots, 6 trees in the third row in from the outside edge were measured. ET_A is the sum of water transpiring from a plant and the evaporation of water from wet leaves and substrates. It was determined by subtracting the weight at midnight from that of the 6 am weight the morning before. The daily change in weight was added to a running total. When cumulative ET_A of a table exceeded 0.6 Kg (1.3 lbs), irrigation was initiated beginning 1 min after midnight. Irrigation frequency for all overhead and flood tables was based on their individual daily ET_A's. Since Aquamats can supply water to trees well beyond the initial wetting of a mat, it is not possible to measure ET_A of a mat by weighing. To resolve this issue, the first flood table was used a sentinel for determining irrigation frequency of all Aquamats. Irrigation was independent for each Aquamat, but all were irrigated the same time.

The same 0.6 Kg trigger weight was in force for overhead irrigated tables until seedlings were ~5 inches tall. Thereafter the change in weight to trigger an irrigation was raised in steps up to 1.2 Kg (3.5 lbs; ½ inch irrigation depth) for overhead irrigated tables to account for water retained in the larger canopies at the 6 am measurement, a result of overhead irrigation. Higher irrigation depths were also needed to re-wet the substrate of overhead irrigated trees during the last 6 weeks before transplanting into citrus pots. To achieve uniform coverage of overhead irrigated trees, the spread of the overhead irrigation system had to extend about 16 inches around all sides. This increased the irrigated area by around 50%, which also fueled the increased volume of water applied by overhead irrigation.

Beginning in mid-March, seedlings were given liquid fertilizer by hand (Peters 20-10-20, 150 ppm N; Everris Intl., The Netherlands) augmented with micronutrients (Diamond R Fertilizer, Winter Garden, FL.) roughly about every 2 weeks until mid-April. Thereafter fertilizer rate was increased to 250 ppm N and applied weekly until trees were transplanted into 4 x 13 inch citrus pots in early June.

Seedling height growth was measured with a ruler beginning in mid-March when germinate rate slowed. For each table, 10 seedling replicates were measured per tray, with 4 trays measured per table. The same seedlings were measured each time. When measured seedling obtained transplant size (6 to 10 inches tall), all seedlings produced were graded for size and root quality. Acceptable seedlings were transplanted in 4 x 14 inch citrus pots using a 60% Canadian peat moss: 40% perlite substrate (Fafard 2P). Seedlings measured during the cell tray stage were kept together within treatments and replications after transplanting and placed under the same irrigation regime as part of a USDA Specialty Crops project. Eighteen grams (½ Tbs) of controlled release fertilizer (Osmocote15-9-12 w/minors, Everris Intl., The Netherlands) was added to the substrate half way down the pot and blended with the substrate, if sub-irrigated, before the seedling was transplanted into the pot. The same fertilizer was applied to the surface of the substrate for trees designated to be overhead irrigated. All trees were given ¼ tsp of copper (Kocide 3000, Du-Pont, Wilmington, DE) and ½ tsp of iron (Sequestrene 139, Syngenta, Basel, Switzerland) as a top dress shortly after potting. Growth measurements of trunk caliper at 5 inches above the soil and tree height continued until 80% of the seedlings obtained minimum caliper dimensions. At that point total irrigation from seed sowing to budding size was summarized for the 3 irrigation systems.

Tree water use

Results and Discussion

Seed germination was very slow in February due to cold temperatures and insufficient heating of the greenhouse. Despite this, seedlings were generally 6 to 10 inches tall the second week of June, when they were transplanted into 4 x 14 inch citrus pots (Fig. 1). There were no differences (*P*=0.07) in seedling heights among the three irrigation systems at the final measurement.

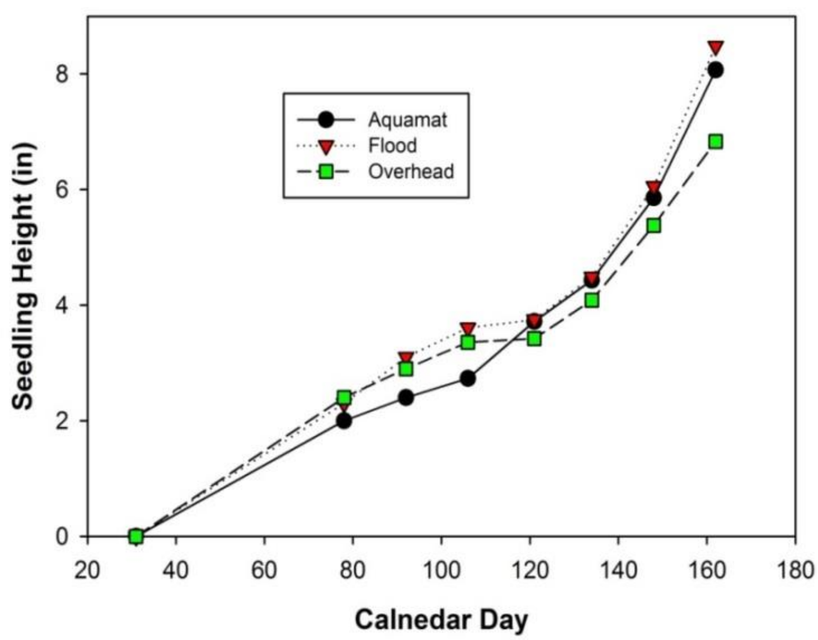

Figure 1. Seedling height growth from sowing the end of January 2014 until seedlings were transplanted from seed trays to citrus pots the second week of June 2014.

Although seedling heights were similar, overhead irrigated trays received nearly 5 times more total irrigation volume than flood irrigated trees; and over 14 times more irrigation than applied to trees grown on the Aquamat (Table 1).

Though differences in irrigation volumes applied to seed trays were very high, total mean ET_A per ft^2 was only about 2-fold greater for overhead irrigated seedlings (Table 1, Line 4). ET_A of Aquamat-grown trees was likely very similar to that of flood irrigated trees, but could not be measured. The higher ET_A of overhead irrigated trees is most likely due to the evaporation of water clinging to leaves and wet surfaces after an irrigation. High humidity in the greenhouse at night limited evaporation of free water on leaves. Neither of these modes of evaporation was prominent for sub-irrigated trays. Seedlings were generally near the same size throughout the data collection period and irrigation frequency was also similar. During the period trees were in the seedling trays, ratios of ET_A to irrigation applied were vastly different. For flood irrigated seedlings, 46 gal of water per ft^2 was applied for each 1 gal of ET_A. For overhead irrigated seedlings, the ratio was 70 gal of water applied per ft^2 for 1 gal of ET_A.

Table 1. Irrigation volumes (gallons) applied **per square foot** of table space to grow seedlings to budding size by irrigation system. Each volume is the mean of 3 replications. Overhead irrigation was applied using 4 spreader nozzles suspended 4 ft above a table and regulated so that the entire area of a table was irrigated with overage to limit hand watering. Flood irrigation was applied as a 0.5 inch depth with two, unregulated ¾ inch drain holes. Aquamat is a self-contained sub-irrigation system using drip tube to disperse water into the mat.

Irrigation system	Overhead	Flood	Aquamat
	gal/ ft^2 of table	gal/ ft^2 of table	gal/ ft^2 of table
1. Irrigation volume seed to seedling transplant	73.8 ± 10.4	15.2 ± 3.82	5.76 ± 0.6
2. Irrigation volume from seedling transplant to budding size trees	10.2 ± 2.4	6.5 ± 0.7	2.0 ± 0.4
3. Mean total irrigation from seed to budding size trees	84.1	21.6	7.8
4. ET_A of seedlings from sowing until transplanted into citrus pots.	1.2 ± 0.1	0.47 ± 0.02	Not Available[z]

[z]NA – ET_A cannot be determined from trees on Aquamats.

Much of the disparity between overhead and sub-irrigation was a result of small plot size. Increasing the area wetted by overhead irrigation to achieve more uniform application also increased the volume of water applied to overhead irrigated tables, about half of which was of no benefit. With larger continuous irrigated areas, such as in commercial operations, irrigation falling outside the planted area would have been a much smaller percentage of the total, likely reducing the volume per ft^2 by 40% or more. However irrigation application for overhead irrigated trays had to be increased to nearly ½ inch per event to re-wet the substrate during the last 6 weeks before transplanting into the citrus pots.

In contrast, sub-irrigation was very successful in re-wetting root balls with much less water and no change in the irrigation volumes applied. By irrigating from below, canopies stayed dry and the root zone appears to have been more fully hydrated after each irrigation event. This is likely the reason both flood and Aquamat-grown trees were taller when transplanted into citrus pots the first of June (Fig. 1). Additionally, it is likely that more fertilizer was available to sub-irrigated trees.

Irrigation volumes for sub-irrigated flood treatments could likely be reduced if only 1 drain hole was used, with further reductions if a zero-pressure drain valve could be installed at an economical cost. This could theoretically lower flood irrigation volume to that of Aquamats.

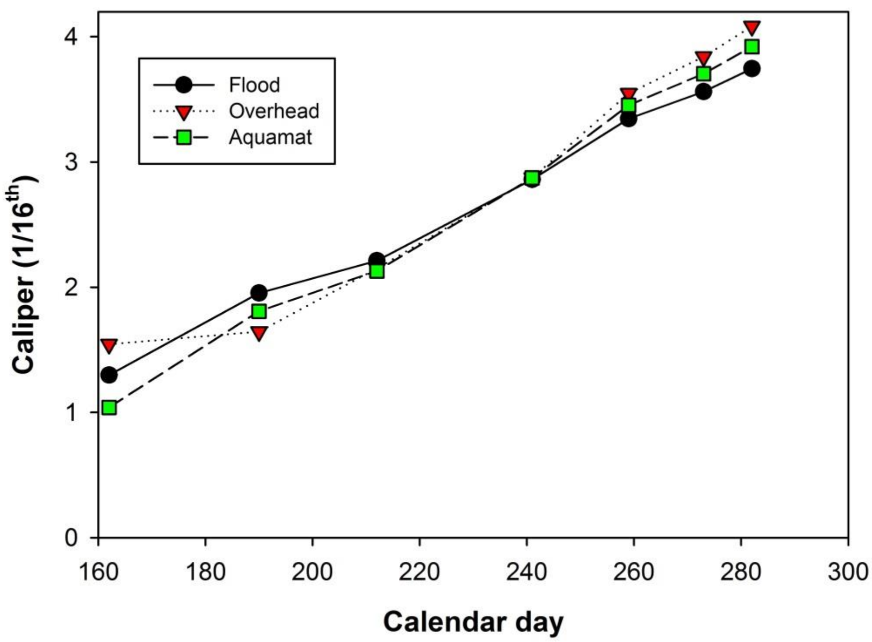

Figure 2. Trunk caliper growth from transplanting into citrus pots the second week of June 2014 until seedlings achieved sufficient caliper for budding measured 5 inches above the substrate in October.

After seedlings were transplanted into citrus pots in early June, it was early October before they achieved trunk calipers of minimum budding size (Fig. 2). By this time, seedling tree height was over 3 ft tall (Fig. 3). There were no differences (P>0.05) in tree caliper or tree height during growth in the citrus pots among the irrigation systems. Over this 3.5 month period, trees irrigated by overhead still required about 5 times as much irrigation as those on Aquamat and twice more water than those flood irrigated (Table 1, Line 2). The more similar differences between overhead and flood irrigation in citrus pots, compared to seedling trays is likely a result of the much larger upper surface area in the 4 in. citrus pots, which allowed more water to be captured. Additionally, the taller and wider spaced stems likely conducted more overhead irrigated water to the root balls.

Measurement of seedling ET_A during the 3.5 month period between potting into citrus pots and development of budding-size trunk calipers was not recorded specifically on these seedlings. However ET_A was recorded during this period for seedlings with similar height. Cumulative mean ET_A for these overhead irrigated trees was 3.137 ± 0.04 gal per tree. For sub-irrigated trees, the average was 0.89 ± 0.22 gal per tree. These values are based on the mean of 6 trees on each of 2 replicate tables per irrigation regime. Trees grown on Aquamats were of similar size to those grown using flood irrigation, and thus likely had similar cumulative ET_A values. The large difference in mean ET_A between the overhead and flood irrigated trees can again be explained by the retention and evaporation of water on the foliage of overhead irrigated trees after an irrigation.

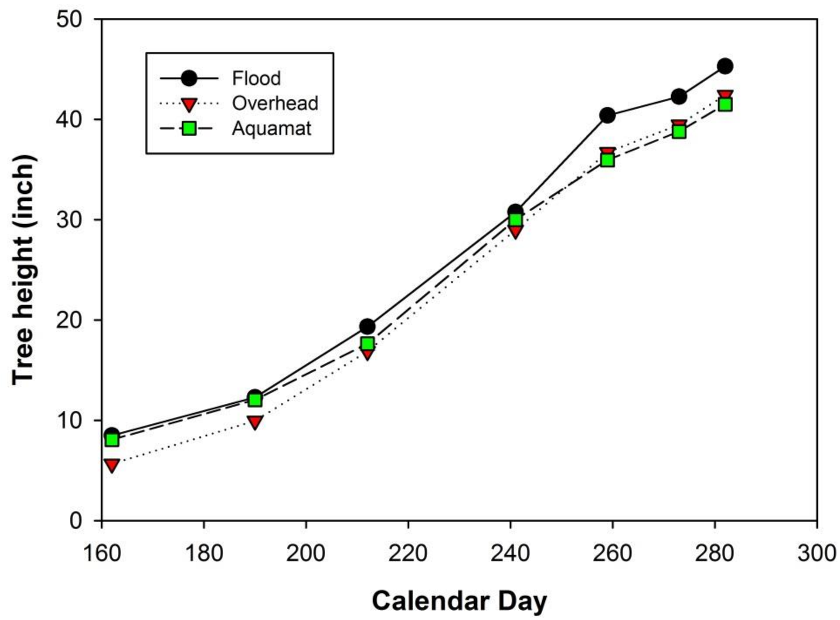

Figure 3. Mean seedling tree height from transplanting into 4 x13 inch citrus pot in early June until trees were budded in early October.

Guidelines for seedling irrigation.

Data presented here is based only on seed sown in mid-January, transplanted in to citrus pots in early June, and collected until trees were budded in early October 2014. Due to trifoliate rootstock sensitivity to short days and/or cold temperatures, it cannot be accurately predicted from this data how total irrigation volumes or ET_A would change if the seeding process was shifted to later periods in the year, or with more adequate heating or future innovations such as supplement lighting. Since heating and lighting are more of a nighttime issue, relatively small increases would be expected. Use of coarser substrates than Farfard 2 (SunGro Inc.; sphagnum peat moss, perlite, vermiculite) in the seedling trays and/or in citrus pots will require more frequent irrigation. Substrates that are moderately coarse or coarser will likely have insufficient capillary rise for sub-irrigation until roots are visible at the bottom of a cell, or very near the bottom of a citrus pot. Thus only general guidelines can be derived from this project.

After sowing, seed trays should be misted to wet cell substrates thoroughly, then on an as needed basis to maintain a damp media to insure germination. In the winter months, cells should be irrigate twice weekly if seeds are planted ½ inch below the top of the substrate, perhaps 3-5 times weekly during the late March to late November warm period. Once about half the seeds have germinated and have roots more than half way to the bottom of the cell, irrigation by sub-irrigation or overhead irrigation can begin.

Seedlings sub-irrigated can be irrigated every third day with about ½ inch of water if the water is allowed to stay in the bench for 3 to 5 min with flood, and to saturation of the Aquamat. As seedlings grow towards 5 inches, irrigation should be increased to every other day in the cool months with generally sunny days. Irrigation should be delayed if it is mostly cloudy. During the summer months, seedlings 5 in. or larger should be irrigated daily. Seedlings over 7 inches tall need daily irrigation with enough water to saturate the substrate in the warm periods and when sunny in the cool periods. This may require twice daily irrigation for overgrown trees.

Seedlings overhead irrigated will require the same frequencies as sub-irrigated trays, but at higher volumes to penetrate the canopies and to be absorbed by the limited surface areas of the cells. By the time overhead irrigated seedlings have formed about a 85% uniform canopy coverage of a tray, overhead irrigation should be applied at ½ inch each event.

Rootstocks recently transplanted into citrus pots should be irrigated well about every 4 days in the cool months and 3 days in the summer months, depending on the water holding capacity of the potting mix. Mixes with large particles, such as coconut coir blends, won't hold much water and will require more frequent irrigation than those composed of mostly peat moss and perlite.

Sub-irrigation in the warm months has been observed to accelerate the growth of roots to the bottom of 14 inch containers by 2 to 3 weeks. Irrigation volumes for flood irrigated trees of that provide up to ½ inch of depth for 4 to 5 minutes should be used. If using Aquamat, once trees approach 30 inches in height or taller, irrigation should occur more frequently than that used for flood irrigation due to the limited waterholding volume of Aquamats. These frequencies should be continued as the trees grow. In the cool season, irrigation was normally required only every 3 to 4 days, and up to 5 days under mostly cloudy conditions.

Once rootstocks have reached 2 ft or more in height, a general rule would be to irrigate every second day during the summer and every 4th to 5th day in the dead of winter.